

Large-Scale Cryogenic Testing of Launch Vehicle Ground Systems at the Kennedy Space Center

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ABSTRACT

The development of a new launch vehicle to support NASA's future exploration plans requires significant redesign and upgrade of Kennedy Space Center's (KSC) launch pad and ground support equipment systems. In many cases, specialized test equipment and systems will be required to certify the function of the new system designs under simulated operational conditions, including propellant loading. This paper provides an overview of the cryogenic test infrastructure that is in place at KSC to conduct development and qualification testing that ranges from the component level to the integrated-system level. An overview of the major cryogenic test facilities will be provided, along with a detailed explanation of the technology focus area for each facility

KEYWORDS: Launch vehicle, ground support equipment, propellant, cryogenic

INTRODUCTION

The operation of Space Transportation systems currently requires the use of significant quantities of cryogenic fluids. The Launch vehicles utilize liquefied hydrogen and oxygen as propellants in order to achieve the efficiencies and thrust necessary to put the payloads (both human and non) into orbit around earth. We have to achieve orbit around the earth before we can return to the moon or continue on to Mars. Providing the cryogenic liquids to the vehicles is the responsibility of the launch facility and in our case, The Kennedy Space Center (KSC). At KSC we have the ability to load and transfer very large quantities of liquid hydrogen and liquid oxygen in a very short period of time. Each launch vehicle has its own unique requirements for how these fluids are delivered and what subsystems are necessary to deliver the fluids to the vehicle. Along with providing the actual flight preparation operations, KSC has the ability to test, validate and qualify the ground support equipment (GSE) that will provide the function of delivering the cryogenics to the vehicle. For Cryogenic operations and testing there are essentially three major facilities available at KSC. They are the Launch Equipment Test Facility (LETf), the Cryogenics Test Laboratory (CTL), and the Integrated System Test Facility (ISTF). In this paper we will give a general overview of each of these facilities provide a summary of the cryogenic capabilities within each area. As the LETf is the primary test facility for qualification of launch pad included.

LAUNCH EQUIPMENT AND TEST FACILITY

The Launch Equipment and Test Facility (LETf) was designed and built in the 70's to support the testing, qualification and validation of the umbilical systems for the Space Shuttle. These included all of the cryogenic supply and vent umbilicals in use by Shuttle today. Over the years the LETf has morphed into a more complex and diverse area for testing, qualification, validation, calibration, proof load testing, and prototype fabrication. The cryogenic capabilities within the LETf proper have migrated to one area where the former Lift Off Simulator was located. The existing cryogenic system is a dual fluid once thru flow system, capable of handling up to 40 gallons per minute of Liquid Hydrogen or similar quantities of Liquid Nitrogen. The LETf is the only facility at KSC that is not a launch facility that is permitted to handle liquid hydrogen in large quantities (12,000 gallon tanker).

The LETf cryogenic system is undergoing a redesign and refurbishment of the cryogenic system in support of the new Constellation Program. The new cryogenics system will still be capable of handling 40 gpm of LH2 on a once thru basis, but then will also be capable of recirculating LN2 from two (2) 15,000 gallon on site LN2 storage dewars. The motive force for the liquid will be an electric pump that can supply sufficient head pressure to the liquid for delivery to the umbilical system being tested and then return the liquid to the storage dewars. The recirculation system will enhance the time and capacity for long duration cryogenic testing.

The delivery piping system is a complex set of valves, pipes and flex hoses designed so that cryogenics can be delivered in a direction consistent with the umbilical being tested from four different locations. The umbilical will be connected to the new Vehicle Motion simulator which will have six degrees of freedom to move the system being tested in an expected manner that the new Ares launch vehicles will operate within. The umbilicals and components being tested can then be operated at cryogenic temperatures and expected operational pressures while being tested for compliance with the positioning of the vehicle.

Some of the past programs that have utilized the LETF (Atlas V, Delta IV, X-33) have shown that when testing and validation are done in parallel with construction fabrication of the Launch Pads a significant scheduling benefit can be obtained.

Testing at KSC utilizes the same or comparable labor pool as the actual launch operations personnel. This allows the people testing the systems to better understand the operations and help to work/improve systems. The test facility has a complete and full data collection (high fidelity) and analysis capability including high speed (20 to 100k Hz), Special instrumentation (e.g. Vibration/position/temperature/pressure/etc.), high fidelity Video and film documentation.

Some of the types of testing that the LETF is capable of are 1) Static Excursions where we can verify compliance of the umbilical or systems through the full range of locations that the system must meet; 2) Motion Excursions where we can verify compliance of the umbilical or systems through the full range of motions and locations under expected acceleration conditions; 3) Liftoff Excursions where we can verify compliance of the umbilical or systems through a simulated liftoff profile, including the disconnecting of the umbilical or system. All of the above tests can be accomplished while maintaining the systems at cryogenic temperatures within a few degrees Kelvin of the Normal Boiling Point of the liquid being used (LH₂ – 20K/37R -253°C/-424°F, LO₂ simulated using LN₂ – 77K/140R -195°C/-320°F and LCH₄ (future) – 112K/202R - 162°C/-297°F). Additionally the systems provide a means of performing Gas (pressure and leak) testing up to 150 PSIG maximum. Special testing can accommodate higher pressures, however not with the cryogenic supply as is currently designed. In addition to the above The LETF can perform a number of simulated weather scenarios while undergoing the aforementioned tests. The simulated weather includes, Rain (water sprays), Wind (fan generated or high pressure gas generated), Sun (both simulated and natural [only simulated is available when testing with LH₂.])

CRYOGENICS TEST LABORATORY

The Cryogenics Test Laboratory (CTL) is a 7000 square feet technology development facility located south of the LETF. There are three individual laboratory areas (~500 square ft/each) that can be used to support specific project needs. A highbay area with 2500 square feet of floor space and a ceiling height of approximately 15 feet is available for larger experiments. Other features of the facility include a class 100 clean room, a technical library, a conference room and external customer office space.

Each of the three laboratories and the highbay area are outfitted with both liquid and gaseous helium and nitrogen supply systems. Liquid nitrogen is supplied from a 5000 gallon storage tank through a vacuum insulated piping header, delivering up to 100 psig via 1-inch bayonet connections into each test area. Liquid helium is supplied to the highbay area from a 1000 gallon storage tank through a vacuum jacketed piping and flexhose manifold. A high volume liquid nitrogen flow system feed from a 6000 gallon tank is capable of flows up to 1000 gallons per minute for short durations. The laboratory also boasts both a gaseous nitrogen and helium supply system capable of delivering controlled pressures from 6000 psig down to 150 psig. A high flow gaseous nitrogen flow test capability is provided at the lab via a 3 inch cross country line (6000 psig nominal supply pressure). Flowrates of 25,000 scfm above 150 psig and 15,000 scfm below 150 psig are available for outside testing at the lab. Other facility systems include a facility vacuum system, capable of developing up to 100 microns and a facility vent tie-in in each lab area. Compressed air is also available throughout the facility.

The technical focus of this lab is to conduct problem-solving technology development work in the area of energy-efficient cryogenics. We combine elements of materials, testing, and application to produce more cost-effective solutions for cryogenic storage and transfer, new cryogenic test equipment and methods, and a pathway to mass-efficient options for space launch and exploration. The laboratory specializes in thermal insulation systems development and testing for the temperature range 4 K to 400 K. A series of custom designed cryostats used to conduct boil-off (evaporative) calorimetry of various insulation materials and systems. Other technology focus areas within the lab include cryogenic component development/testing, low-temperature applications and propellant servicing systems.

THE INTEGRATED SYSTEMS TEST FACILITY

The Integrated Systems Test Facility (ISTF) is located at Launch Complex 20 on the Cape Canaveral Air Force Station. The ISTF utilizes the former blockhouse for control and data acquisition. The ISTF currently has the liquid oxygen systems in place and ready for operations. The LO2 system consists of two 28,000 gallon dewars for storage and return of the recirculating LO2. Motive force for the LO2 is provided by a large centrifugal pump capable of flowing in excess of 1000 gallons per minute. The piping systems associated with the ISTF are configured in such a manner that multiple size and flow configurations can be tested. The systems are set up to be tested remotely from the block house providing a level of safety and security only available at an active launch facility.